The Remarkable Story of Maxwell and Tait[1]

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In the Fellow's Parlour of Trinity College, Cambridge hangs a portrait of one of its most distinguished Fellows, James Clerk Maxwell. In the Hall of Peterhouse College, Cambridge hangs a portrait of one of its most distinguished Fellows, Peter Guthrie Tait. History was to dictate that the lives of these two physicists would be inextricably linked.

Maxwell was born on 13 June 1831, Peter Guthrie Tait less than seven weeks earlier on 28 April. When he was eight years old, Maxwell's mother died and he was brought up by his father and his widowed aunt Isabella Wedderburn (née Clerk) who had been married to James Wedderburn, Solicitor General for Scotland. Tait was much the same age when he lost his father and his mother turned to his uncle John Ronaldson to help her raise the family.

The two men's lives continued in parallel or, at least, almost so. Both were enrolled as pupils at the Edinburgh Academy. Tait entered the class of James Cumming, a classicist who would remain its teacher right through until the class left school but, when Maxwell's father came to enrol Maxwell rather late in the day, the Cumming class was full. Maxwell therefore had to enrol in the year above (the Carmichael class) where the boys were that much older. So during their time at the Academy Maxwell was always a year ahead of Tait. The academic record of both pupils was recorded at the time. The Academical Club Prizes were open to all members of the school and therefore in 1846 and 1847 Maxwell and Tait came into direct competition for the first time, honours to Tait in 1846 and to Maxwell in 1847.

Year	Class Prizes - Maxwell	Class Prizes - Tait
1842	No Mention	Dux 1st Class; 1st English reader, 2nd in English
1843	19th in 3rd class; 1st in Scripture Biography.	Dux 2nd Class; 2nd in English.
1844	? in 4th Class; 1st in Scripture Biography.	Dux 3rd Class; 4th in Arithmetic.
1845	11th in 5th Class; Silver Medal of Academical Club; 1st in English Verses.	Dux 4th Class; 1st in Latin Verses; 1st in Arithmetic.
1846	5th in 6th Class; 1st in English Verses and in English; 2nd in Mathematics.	Dux 5th Class; 2nd in English; 1st in French

[1] This article is a slightly amended version of an article which appeared in the James Clerk Maxwell Commemorative Booklet which was issued on the occasion of the Fourth International Congress on Industrial and Applied Mathematics coming to Edinburgh in July 1999.

1846 Academical Club Prizes	6th overall; 3rd in Mathematics, in History, in Geography and in Scripture Biography; 6th in English and in French.	3rd overall; 1st in Mathematics; 3rd in History, in Geography and in Scripture Biography; 5th in English and in French; 10th in Latin.
1847	1st in Mathematics in 7th Class; Silver Medal.	Dux 6th Class; 1st in Mathematics and in Latin Verses; 2nd in French and in Physical Science.
1847 Academical Club Prizes	2nd overall; 1st in Mathematics and in English; 2nd in Latin; 4th = in Greek;	3rd overall; 2nd in Mathematics; 3rd = in Latin; 4th = in English.

First place, or Dux, in the Academical Club Prizes of 1847 was taken by Lewis Campbell, a lifelong friend of Maxwell and later his biographer. Subsequently, Lewis Campbell was Blackstone Medallist at Glasgow University, Snell Exhibitioner of Balliol College, Oxford where he took First Class Honours in Greats. After a Fellowship at Balliol he was elected Professor of Greek at St. Andrew's University. A fellow pupil in Tait's class was Fleeming Jenkin, LL.D., F.R.S.E., F.R.S. Professor of Engineering at Edinburgh University. Jenkin was later to collaborate with Maxwell in the determination of electrical standards. It is clear from the subsequent attainments of Maxwell, Tait, Campbell and Jenkin that the academic level at the Edinburgh Academy was particularly high in these years.

During his time at the Academy Tait kept a notebook in which he noted down mathematical results and proofs - this is now on loan to the James Clerk Maxwell Foundation - and in the notebook are a number of results and proofs in Maxwell's writing. With regard to their time at the Edinburgh Academy, Tait records in his obituary tribute to Maxwell (Proceedings of the Royal Society of Edinburgh, vol. x, session 1979-80) :-

> …….we discussed together, with schoolboy enthusiasm, numerous curious problems, among which I remember particularly the various plane sections of a ring or tore, and the form of a cylindrical mirror which should show one his own image unperverted. I still possess some of the manuscripts which we exchanged in 1846 and early in 1847. Those by Maxwell are on *The Conical Pendulum*, *Descartes' Ovals*, *Meloid and Apioid* and *Trifocal Curves*. All are drawn up in strict geometrical form and divided into consecutive propositions. The three latter are connected with his first published paper, communicated by Forbes to this Society and printed in our Proceedings, vol. ii, under the title *On the Description of oval curves, and those having plurality of foci* (1846).

At the end of 1847 Maxwell and Tait left the Edinburgh Academy and both proceeded to Edinburgh University. The Professor of Mathematics was Philip Kelland and the Professor of Natural Philosophy was James Forbes. Kelland had three mathematics classes whilst Forbes had one class divided into three divisions. Tait put himself into the top Mathematics class and the first division of Natural Philosophy. Maxwell decided to take things more easily and put himself in the second division of Natural Philosophy. It is not clear which mathematics class he took.

Maxwell was to stay at Edinburgh University for three years (Forbes gave him the run of his laboratory) but Tait took the honours exam at the end of 1848 (being third on the honours list, the Gold Medal going to James Sime, recognised in his day as one of the most able students ever to enter Edinburgh University). The Gold Medal did not fall to Maxwell either in his final year at Edinburgh but the family honour would be upheld a few years later when the Straiton Gold Medal was won by Maxwell's first cousin, William Dyce Cay, later a distinguished engineer.

Tait moved on to Peterhouse College, Cambridge and it must have been thought at this stage that Tait was the more brilliant of the two, particularly when Tait emerged as Senior Wrangler and First Smith's Prizeman in 1852, these two distinctions being considered the highest intellectual achievements attainable in Britain. Indeed, Tait is believed to be the youngest Senior Wrangler on record being then aged 20. James Gloag, the mathematics master who had taught Tait and Maxwell at the Edinburgh Academy, was 'beside himself' at Tait's achievement and considered the credit entirely his own!

During his time at Edinburgh University, Maxwell had had time to present two papers to the Royal Society of Edinburgh, *'On the Theory of Rolling Curves'* and *'On the Equilibrium of Elastic Solids'*. He also did much useful research on the Theory of Colour using the resources of Forbes' laboratory. These early successes in mathematics and physics perhaps awakened his father to the possibility that young James would not follow in the footsteps of so many family members and enter the legal profession but it was only when Forbes personally reassured him that Maxwell's abilities were matched by his burgeoning maturity that the decision was taken to send him up to Cambridge. It was at the end of 1850 therefore before he proceeded to Peterhouse (St Peter's College) where Tait was starting his third year. After just one term there, however, Maxwell changed colleges to Trinity. It is not quite clear why this migration took place; possible reasons are that, with students of the calibre of Tait, Steele and Routh at Peterhouse, the chances of a Fellowship were higher at Trinity. Alternatively, Maxwell may have found Peterhouse too narrowly mathematical whereas at Trinity he could mix and hold his own across a vast range of learning with the broader based intellegentia - more stimulating for someone with the range of Maxwell.

When the Tripos came in January 1854, Maxwell was placed second (to Routh) but first equal with Routh in the Smith's Prize. Gloag was again 'beside himself'. It cannot but be regarded as extraordinary that the only First Smith's Prizemen ever to come from the Edinburgh Academy had both been at the school at the same time. Rather remarkably one of the examiners when both Maxwell and Tait took the Tripos was Charles Mackenzie who had also been educated at the Edinburgh Academy and who had been Second Wrangler in 1848. As was said, Gloag had all his pupils in the right place when it came to the Tripos!

Tait, after a couple of years as a Fellow of Peterhouse, was elected in September 1854 as Professor of Mathematics at Queens University, Belfast. In 1855, Maxwell was appointed a Fellow of Trinity and both he and Tait settled down to a life of research. At age 24, in April 1856, the Fellowship of the Royal Society of Edinburgh was conferred on Maxwell. And all this time, at school and at university, there was no evidence of any rivalry or jealousy as surely there might have been - indeed quite the opposite - the two were on the most friendly of terms.

In 1856 Maxwell applied for the Chair of Natural Philosophy at Marischal College in Aberdeen and was successful. Although the records of the University of Aberdeen are not extant to verify the

fact, it is believed that Tait also applied for the Aberdeen Chair. If this is the case, it is another example of Maxwell and Tait coming into competition. It is however well authenticated that in the spring of 1860, on the retirement of Forbes, there fell vacant the prestigious chair of Natural Philosophy at Edinburgh University and Maxwell and Tait, both with professorial experience, quietly declared their interest. The selection panel consisted of four city elders and three representatives of the university, among them Gladstone, then Chancellor of the Exchequer. The 'weapons', as Maxwell dubbed them were to be 'testimonials, common gossip and diplomacy'. When Tait was declared the successful candidate, the local press, in the form of the Edinburgh *Courant*, attributed his success to his superiority in the lecture theatre, noting that neither men had yet established a first-rate research record. In those days an impressive delivery in the lecture theatre was regarded as a necessary attribute for a professor. 'Never, I think, can there have been a more superb demonstrator', claimed J. M. Barrie, a student later to gain fame as the creator of *Peter Pan*. Maxwell's faltering delivery did not bear favourable comparison. Whether common or informed, gossip had served him ill.

The evidence of Maxwell's superiority in research was, of course, already available to those with their eyes open. His investigation of the conditions required for the stability of Saturn's rings oozed originality. Yet, Thomson, Forbes, Stokes and Hopkins merely resubmitted the testimonials in support of Maxwell which they had proffered to the authorities at Marischal College four years earlier and Faraday, as was his want, declined to provide a reference at all. Only Airy drew attention to the fertility of Maxwell's theoretical astrophysics. As a body then his referees appear to have lapsed into shameful indolence or, more likely, failed wholly to grasp the significance of Maxwell's work. Whatever the truth of the matter, it would be Tait, and not Maxwell, who would preside over the development of physics at Edinburgh right through to the century's end.

Maxwell faced this setback with enormous dignity and courage. He had only recently learnt that he was being squeezed out in the amalgamation of the two Aberdeen colleges, and being squeezed out by a minor scientist at that. Furthermore, in the January issue of the *Philosophical Magazine* he had presented the first part of 'Illustrations of the dynamical theory of gases', a seminal work in statistical physics, his name appearing proudly in the contents as Professor Clerk Maxwell. By July, when the second part appeared, its author, discarded by Aberdeen and passed over by Edinburgh, had reverted to plain Mr Clerk Maxwell. The early part of 1860 was a very rough period for Maxwell and there is no record of how he felt, but the events did not seem in any way to affect the relationship between him and Tait. Indeed, each had the highest regard for the abilities of the other which were freely put at the other's disposal.

From this period onwards, the tide began to turn in Maxwell's favour. No-one could unravel the secrets of Nature as Maxwell could and the papers coming from Maxwell's pen were in the premier division in world terms. At the age of just 29, in June 1861, Fellowship of the Royal Society followed. Tait was very good but his 'nose' for investigating physical phenomena was not in the same league as Maxwell's; his 'nose' was more attuned to pure mathematics as is evidenced by his skill some years later in developing, almost from scratch, the Mathematical Theory of Knots and his exposition of the Theory of Quaternions originated by Hamilton. Maxwell deferred to Tait on purely mathematical subjects. Tait was elected FRSE in the year 1861.

After the two men went their separate ways in the mid-1850s they met only infrequently. Tait showed a reluctance to venture south of the border, whilst Maxwell spent a number of years both at King's College, London and at the Cavendish Laboratory in Cambridge. Tait's friendship with

Thomson developed through their collaboration on their *Treatise on Natural Philosophy* and their frequent face-to-face meetings: that with Maxwell flourished only through their copious correspondence, brought together in recent times by Harman. Characterised by its humour, its warmth, its literary quotations and, of course, its serious scientific debate, what a fascinating interchange it is.

The Library of the University of Cambridge contains some 167 scientific letters exchanged between Maxwell and Tait, often in the form of postcards because of the favourable ha'penny postage rate! However these are only part of their scientific correspondence, the remainder of which has been lost. The two men used each other as sounding boards, constantly bouncing ideas to and fro, seeking second opinions, reviewing proofs of books and papers (as they also did in correspondence with Lord Kelvin).

The earliest extant item of this correspondence is the letter which Maxwell wrote to Tait on 3 December 1856, containing a plea that Tait act as a link to the external world of professional mathematics and physics:

> *I should feel deeply gratified in perusing anything that might fall from your pen illustrative of the present state and occupation of the Mathematical Chair of your College.*

The warmth of their friendship is evident in many of their communications (Maxwell to Tait, 9 March 1859):

> *Many thanks for the felicitations of the 26th Ult. and may you long be preserved from the claw of the cat, the iodide of cyanogen and the puncture of the scalpel.*

In their correspondence, there is a good deal of chat about other physicists, so much so that in most cases their names are pared to little more than initial letters. Tait becomes T′ in deference to Thomson, who is T. In February 1871 he suggests Maxwell adopts dp/dt because of his initials J. C. M and the equation in Tait's book on thermodynamics dp/dt = JCM. In time Tyndall is reduced to T″ (a scientist of the second order), Clausius to C, Hamilton to H and Helmholtz to H^2. Pressed for space as they switch to using postcards domains of physics go on a Greek diet - thermodynamics becomes $\Theta\Delta^{cs}$ and spherical harmonics, Σφαρξ. Now the two physicists are playing with transliteration, simply taking the sounds of characters in another alphabet and interpreting them in English. Like a highly-intelligent youth Maxwell begins a letter of March 1873: -

> O T′
> Θαγξ φορ Αλλεξ (i.e. Thanks for everything)

By this time the frivolity is already in full swing. Members of the British Association for the Advancement of Science are routinely referred to as 'British Asses'. To indicate a change of address Maxwell begins a letter with the reference Lat 55, Long 4 (his estate at Glenlair) but he also appends a decimal date, 1868.534 (1868 being a leap year, this is 14 July). A later missive (7 December 1871) contains dates as limits of integration. And in the spring of 1873, Lewis Carroll's *Through the Looking Glass* having been published the previous year, Maxwell chides Tait, in mirror writing:

Why have you forgotten to send Alice.
We remain in Wonderland till she appears.

Characters from Dickens put in guest appearances. Immortal lines are borrowed from Byron and from Aristophanes - in the original Greek, of course. Indeed, such was their felicity with language that they would take pleasure in composing verse of their own, especially if they could gently tease their fellow scientists in the process. Prompted by Tait's equating of FRSE and Pharisee (in a postcard of May 1871) Maxwell pens a stanza dedicated to the Royal Society of Edinburgh and Tait adds an answering octave:

The FRSE (Pharisee)

Where Wordsworth's Swan was apt to float
The man of science from his boat
In flasks and phials carefully
Collects the lively water Flea
Then analyses with great pains
The water which from Flea he drains.
Water and fleas! The trout below
Delights when through his gills they flow
He too the precious mixture drains
Water ejects and Flea retains
The Edinburgh Pharisee
Receives both water, fish and Flea
The water Flea he filters out
Then unsuspecting eats the trout (by dp/dt)

That trout indeed is wondrous bad
Enough to drive the eater mad
For 'tis but concentrated Flea
Flea smaller animalculae
These feed on spores and deadly germs
With which their stomach comes to terms
Think! Edinburgh Pharisee!
How they will work their will on thee! (by T')

(Poem reproduced by kind permission of Murray Tait, great grandson of P G Tait.)

Most important of all is the influence each man had on the other's scientific thinking, influence all too evident from a brief examination of two periods of intensive activity in the correspondence: some seven letters in six weeks towards the end of 1867 and a further fourteen letters in six weeks in 1871.

The first period sees Maxwell excited at the prospect of exploiting Tait's interest in Helmholtz's 'water twists' in electromagnetic theory and, perhaps inadvertently acting with Kelvin to persuade Tait to undertake a census of knot designs. Tait is keen to pick Maxwell's brain on the same subject but also to persuade his friend, now retired from King's College, London and living the life of a country gentleman at Glenlair, to make a contribution to Scotland's premier scientific institution. Tait writes to Maxwell on 6.12.1867:-

Please remember that you are a Fellow of the R. S. E. and be good enough to send us a paper on Knots and their possible equations in 3 dimensions…. Give us a paper on these like a good fellow -whether for the Trans. or merely for the Proc.

P.S. Ponder this proposition. A man of your originality and fertility and leisure is undoubtedly bound to furnish to the chief Society of his native land, numerous papers, however short.

Tait to Maxwell on 13.12.67:-

Can't you contrive .....to spend a winter in Edinburgh? In that case we should at once put you on the Council of the R. S. E. and get some good out of you. Also you should have the run of my laboratory….as well as those of Playfair, Crum Brown etc. Ponder the point.

At the same time Maxwell is struggling with questions fundamental to thermodynamics. It is to Tait that he mentions in a letter of 11 December the possibility of employing between two vessels containing elastic molecules 'a finite being who knows the paths and velocities of all the molecules by simple inspection but who can do no work except to open and close a hole in the diaphragm', the very being that Kelvin would dub 'Maxwell's Demon'.

In the second period Maxwell leans heavily upon his friend as he attempts to couch his theory of electromagnetism in a form which will be understandable. The issue for Tait is to persuade Maxwell to help free physics from the straightjacket of co-ordinates; for Maxwell it is to come to an agreed nomenclature, a standardised notation, a common geometrical representation. At times Maxwell appears anxious, as in a postcard of 8 May 1871:

I am desolated! I am like the Ninevites! Which is my right hand? Am I perverted? a mere man in a mirror, walking in a vain show?

Reassured by Tait's response and a ruling by the newly-instituted London Mathematical Society he settles on a right-handed configuration of the three orthogonal axes, symbolised by the tendril of the vine and writes to Tait:

..... I thank you and praise you for turning me from the system of the hop to that of the vine. I have perverted the whole of electromagnetics to suit.

Maxwell was the President of the Mathematics and Physics Section of the British Association for the Advancement of Science at their 1870 meeting in Liverpool while Tait was the President at the next meeting in Edinburgh in 1871. On that occasion Jenkin was President of the Mechanical Sciences Section.

On the occasion of inviting Tait to give the Rede Lecture in the Cambridge Senate House in 1873, Maxwell writes as follows:-

I have no Assistant. If I can do you any service well and good, if not, why not? Professor Liveing will lend you his bags, give you his gases and furnish you with lime light. If you are particular about your lantern bring it yourself like Guy Fawkes or the man in the Moon…. The Senate House is a place to write in, graduate in and to vote in. The Public Orator can speak in it provided he employs

the Latin tongue. What those venerable walls would say if the vernacular were sounded within them I dare not even think….

On the occasion of Maxwell inviting Tait to be the Additional Examiner in the Mathematical Tripos in 1875, Maxwell writes as follows:-

I shall be glad if you can see your way to being addle x. (Additional Examiner). *Having experienced your written criticisms I desire to extend the benefit of them to others.*

Finally, what of Maxwell's and Tait's public pronouncements on each other's achievements?

Tait was aware of Maxwell's enormous potential even as a teenager. Writing later about their school days in the 'Chronicles of the Cumming Club', he says of Maxwell, simply:

It was in those days that some of the early developments of genius showed themselves……

Contained in the 1947 Edition of the Encyclopædia Britannica is the entry about Maxwell which was written by Tait. In it he says:

The first paper of Maxwell's in which an attempt at an admissible physical theory of electromagnetism was made was communicated to the Royal Society in 1864. But the theory in fully developed form first appeared in 1873 in his great treatise of Electricity and Magnetism. This work was one of the most splendid monuments ever raised by the genius of a single individual.

Whilst Maxwell was elected to Fellowship of the Royal Society at an early age it was never bestowed upon Tait. Perhaps the greatest acclaim he received came in the form of the Keith Prize of the Royal Society of Edinburgh in 1870, following the publication of two quaternion papers. A laudatory note composed by Maxwell for the occasion of the prize-giving described the first paper as 'very powerful', the second as 'really great' and it painted a picture of Tait as a profound thinker. A couple of years later, following the publication of Maxwell's *Treatise on Electricity and Magnetism*, an 'anonymous' review appeared in the journal *Nature*. In reference to Maxwell's name the reviewer wrote that it,

'requires only the stamp of antiquity to raise it almost to the level of that of Newton'.

These were undoubtedly the words of Tait. It would be cynical to view these two examples as nothing more than exercises in mutual back-patting. They are a reflection of a genuine appreciation of each other's talents.

Finally, when Maxwell died at the age of 48 in 1879, it was natural that the scientific community should turn to Tait to write the obituary. Perhaps the only alternative would have been Kelvin but he had never accepted Maxwell's electromagnetic theory. Tait, by contrast, had been one of the first to recognise Maxwell's greatness and the profound significance for science of Maxwell's marvellous equations.